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Natural Fiber in Cement and Concrete Matrices - A Review

Vikas Srivastava[1*], P.K.Mehta[2], Satyendra Nath[3]

[1*]Department of Civil Engineering, SHIATS, Allahabad.
[2]Department of Civil Engineering, MNNIT, Allahabad.
[3]Department of Environmental Science, SHIATS, Allahabad.

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Abstract

The natural fibres, abundantly available in nature and also generated as agricultural waste, can be used advantageously in improving certain physical properties of cement matrix and concrete, even though the durability of resultant mix is relatively poor. As compared to the fibres widely used in construction activities viz. steel, glass carbon synthetic etc., these are advantageous in the sense that they are renewable, non abrasive, cheaper, comparatively more flexible etc. Also, the health and safety concerns during their handling, processing and mixing are less. Several natural fibres have been used in experimental studies and construction activities to investigate and improve upon the mechanical properties of cement and concrete matrices which are brittle in nature. This paper presents a review of the effects of natural fiber inclusion on the mechanical properties of cement and concrete matrices in green and hardened state.

Keywords: *Brittle matrix; Mechanical properties; Natural fibres.*

1. INTRODUCTION

Agriculture is the sector which employs the majority of population. Also, it generates a lot of waste material after sawing of the crops. Majority of the agriculture wastes generated are used as a fuel in the rural house holds. However, there are several crops which yield various types of fibres and these have been used in the preparation of various articles since ages. These fibres can be used in rural construction activities too viz., construction of houses, plastering of the walls, construction of rural society amenities as these are freely and abundantly available there. Further, the use of natural fibres in rural construction activities will result in economical structures which will be stronger and more durable thereby solving one of the major deficiencies in rural structures.

The natural fiberes have the potential to be used as reinforcement in cement and concrete matrices to overcome some inherent deficiencies of these materials. These fibres are advantageous as compared to widely used artificial fibres because they are cheaper, renewable, non abrasive, abundant and do not create health and safety problems during handling, processing and mixing operations. The fibres which have been tried to improve the mechanical properties of cement and concrete matrix are coconut, sugarcane bagesse, banana, san, date-palm, coir, eucalyptus, flax, bamboo, agava, elephant grass, sisal, roselle etc. The mechanical properties of cement and concrete matrices improved are crack resistance, fracture toughness, compressive temperature, flexural, bond and impact strength.

***Vikas Srivastava Tel.: +919415369170**
E-mail : vikas_mes@rediffmail.com

During last three- four decades considerable efforts were made to investigate the effects of natural fibre inclusion, as randomly distributed reinforcement in cement and concrete matrix with a view to provide cost effective building materials. Of several natural fibres available, the san fibre is found to be most advantageous in improving the flexural and tensile strength. Coir fibre is found to b e best for improving the impact strength of cement and concrete matrices. The main problem faced in using these fibres, abundantly available in tropical and sub tropical regions, is durability performance of the cement and concrete matrix thus produced. The severe degradation of exposed composites can also be attributed to interfacial damages due to continuous volume changes of the vegetable fibres inside the cement matrix (John ***et al.*** 1989). Durability of natural fibres could be improved either by protection of fibres by coating or sealing them to avoid the effect of alkalinity or by reduction of free alkalis in the matrix, by developing low alkaline binders based on industrial and agricultural by products(Agopyan and Jhon, 1992). The properties of fresh and hardened concrete made using natural fibres are presented below.

Workability

Siddiqui (2004) reported that the slump decreased with an increase in the percentage of san fibres. Also, these fibres adversely affected the Vee Bee time of concrete.

Crack Resistance

Rama Krishna *et al.* (2005) reported that the maximum crack width and length are not sensitive to the type and contact of the fibres. However, the ultimate crack resistance is affected significantly by use of coir fibres. The ultimate crack resistance was found to increase with the fibre content. It is also reported that the average increase in the crack resistance ratio (C_{rs}), considering the lower and upper bounds of fiber contact used, is highest for coir fibre reinforced slab. (Sravastano *et al.* 2009) reported that the evidence of crack - bridging and fibre pullout was observed on the fractured surface of the R~ curve (Resistance to fracture curve) specimen. It is also reported that the stable fatigue crack growth of the natural fibre cementious composite may be attributed to degradation of bridging zones. (Boghossion and Wegner 2008) reported that the addition of low volume fraction of short flax fibers to Peortland cement mortar is effective in reducing the cracks resulting from the restrained plastic shrinkage under condition that produce high evaporation rates. It is also reported that the improvement increased with increasing volume fraction but the variation in fibre lengths (10 mm and 38 mm) did not significantly influence the cracking behavior. (Savastano *et al.* 2005) reported that the matrix cracking occurred close to the fibers as a result of internal tensile stresses generated by volume changes in the fibers. (Filho and Sanjuan 1999) have reported that the addition of 25 mm long sisal fibres (0.2% volume fraction) reduced free plastic shrinkage strains and also reduced cracks widths in restrained ring type specimen of cement mortars. Soroushian and Ravanbakhsh (1998) have also reported that cellulose fibres (0.06% volume fraction) reduced plastic shrinkage crack area by 78% relative to plain concrete.

Fracture Toughness

Savastano *et al.* (2009) reported that toughening in the natural fibre reinforced composites occurs largely as a result of crack bridging. It is also reported that the intrinsic toughness of the natural fibre cement composites reinforced with sisal, banana and eucalyptus fibres was between 1.2 and 1.4 MPa Vm. (Siddiqui 2004) included san fibres (0.30 - 0.90%) in fly ash concrete (fly ash content 30 - 50%) and reported that the fracture toughness of concrete matrix increased with fibre content. The maximum increase in fracture toughness was found at fibre content of 0.9%. The increase was about 7.2, 4.9 and 3.7 times for concrete matrix with fly ash content 30, 40 and 50% respectively at 28 days. At 91 days, the respective changes were 4.9, 3.8 and 2.6times. (Reis 2006) reported that the chopped coconut fibre and sugarcane bagasse fibre

increase the fracture properties - both fracture toughness and fracture energy of polymer concrete.

Compressive Strength

Siddiqui , 2004 reported that the addition of san fibres decreased marginally the compressive strength of fly ash concrete. The decrease was 8 - 13%, 4 - 8% and 2 - 9% at 35, 45 and 55% fly ash content. (Kriker *et al*. 2005) have reported that in water curing, the vegetable fibre reinforced concrete is marginally better in respect of compressive strength. Siddiqui(lO) reported that in san fibre reinforced fly ash concrete at 28 days, a reduction in compressive strength between 2 to 12% was observed depending on the fly ash content and fibre percentage. However at 91 days, the compressive strength of san fibre reinforced high volume fly ash concrete increased. (Ismail 2007) reported that compressive strength and bulk density are slightly increased at low fibre content (0.3 to 1.5% by volume). However beyond a fibre content of 1.5%, a reduction in compressive strength of about 8.2% for every 0.5% fibre volume increase was observed.

Tensile Strength

Siddiqui , 2004 reported that addition of san fibre increases the tensile strength of fly ash concrete in the range of 11 - 8% at a fibre content of 0.25% and 27 - 22% for fibre content of 0.75% in case of high volume fly ash concrete (Fly ash - 35, 45 and 55%). (Ismail , 2007) reported that at lower fibre content (0.3%), the tensile strength decreased slightly (11.4%), while it increased by about 53% at 4% fibre content.

Flexural Strength

Reis 2006; Reis 2003; Ferreira 2004 reported that coconut fibre reinforcement improved the flexural properties of epoxy polymer concrete and this improvement is more than the glass and carbon fibre reinforced concrete. The Coconut fibre increased the flexural strength by about 25% as compared to referral unreinforced concrete. It is also reported that sugarcane bagasse improved slightly (3.5%) the flexural strength. Siddiqui (2004) reported that addition of san fibre increased the flexural strength of fly ash concrete. This increase is about 5% at 0.25% fibre content while at 0.75% fibre content the increase is about 10%. The addition of twines of natural san fibre enhanced the load carrying capacity and ductility (Siddiqui, 2004). (Savastano *et al*. 1999) reported that the modulus of rupture (MOR) of coir fibre reinforced composite was 18% more than that of referral at same w/c ratio. It is also reported that composite made with Eucalyptus pulp has 16.5% higher MOR as compared to referral.

Bond Strength

Savastano *et al*. 2005 reported that sisal and eucalyptus grandic pulped fibres give satisfactory bonding in OPC matrices.

Impact Strength

Siddiqui included san fibre (0.30 - 0.90%) in fly ash concrete (fly ash content, 30 - 50%) and reported that the addition of san fibres significantly enhanced the impact strength which increased with the fibre content (0.30 to 0.90%). The increase in impact strength was observed 1 to 3 times at 28 days and 1.5 to 3.5 times at 91 days. (Ramakrishna *et al*. 2005) reported that the impact resistance of natural fibre reinforced cement mortar slabs is 3 to 18 times higher than that of plain cement mortar slabs. It is also reported that the residual impact strength ratio (l_{rs}) of natural fibre reinforced slab specimens ranges between 1.87 to 3.9 reported that the natural fibres enhanced the impact resistance of concrete and exhibited response comparable to the glass fibre. Siddiqui (2005) reported that the addition of san fibre significantly enhanced the impact strength and it increased with the fibre .. content (0.25 to 0.75%). The increase in impact strength was 2 -3 times, 1.5 - 2.0 times and 1.0 - 1.5 times in fly ash concrete with fly ash content 35, 45 and 55% respectively.

From the above study it may be concluded that the use of fibres generated from agricultural

activities in rural and urban areas construction material and practices modifies beneficially the cracking behavior of concrete and cement matrices. This results in stronger, safe and economical structures in rural areas where these are freely and easily available. The workability is adversely affected by fibre addition. The fibre addition improves significantly the crack resistance. Also, the crack width is reduced. The fracture toughness of natural fibre composites is greatly improved. The compressive strength of natural fibre composites is not affected much upto certain fibre content. In general, the tensile strength of natural fibre composites is improved significantly. The fibre inclusion, in general, significantly improves the flexural strength and ductility of matrices. The bond of natural fibres in composites is satisfactory. The fibre inclusion greatly enhances the impact strength of composites.

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